LALP-03-105

2002 Proton Radiography Overview

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The Proton Radiography (pRad) program at Los Alamos Neutron Science Center (LANSCE) is investigating weapons-physics issues related to the detonation of high explosives (HE) along with the equation of state of the burned HE products, the dynamic failure processes of explosively driven metals such as spall and shear banding, and the hydrodynamics of implosions. This program provides the unique capability of studying the evolution of explosive processes with high spatial and temporal resolution. With this technique, 800-MeV protons provided by the LANSCE linear accelerator penetrate directly through the dynamic system (Fig. 1). The protons, delivered in 50- to 100-ns-long pulses, interact with the material of the dynamic system in a containment vessel (Fig. 2) and undergo scattering that is proportional to the product of the density and thickness of the material. The configuration of the materials, which are moving with typical velocities of ~ 1 mm/µs, is effectively frozen during the short duration of the proton pulses. These protons are then transported from the object through a magnetic lens to a Fourier point where protons are intercepted if they are scattered to angles larger than some maximum cutoff. This cutoff angle provides the image contrast whereby the proton density is lowered for protons passing through thicker materials. The protons surviving the cutoff angle are then magnetically transported to a scintillator located at an image location where the proton positions are identical to their initial positions at the object location. The scintillator converts the proton flux to light, which is collected by a series of fast-gated cameras. The multiple images are separated in time by typically 1 µs for up to 21 pulses per dynamic event. These images can then be combined to produce a motion picture of the dynamic event in which materials travel ~ 1 mm between frames.

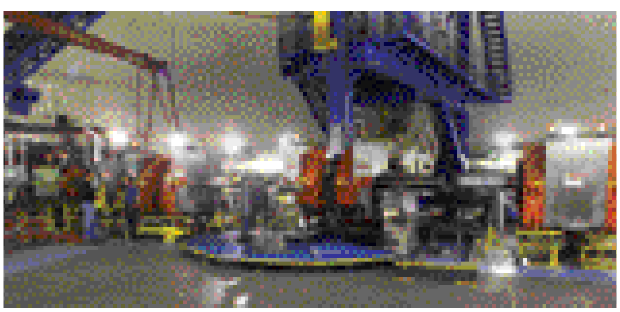

Fig. 1. Panoramic view of the pRad facility.[1]

In 2002, 42 dynamic pRad experiments — a pRad-shot record — were performed at LANSCE in support of the weapons-physics efforts at Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), Lawrence Livermore National Laboratory (LLNL), and the Aldermaston Weapons Establishment (AWE), bringing the total number of dynamic pRad experiments performed at LANSCE to 156. For these shots, the LANSCE accelerator and beam-delivery complex provided protons with 100% reliability. In addition to these dynamic experiments, beam time was used for detector and concept development and for the radiography of mockups to determine shot configurations and the design of future experiments.

The 42 pRad shots in 2002 fell into three categories: (1) outside-user experiments, (2) studies of HE burn characteristics, and (3) the study of material failure mechanisms such as spall and shear banding. Two experiments were fired for SNL to continue investigations on the dynamics of explosively driven voltage bars used for neutron generators. Three experiments were performed with LLNL to study the material-failure characteristics of steel under various shear- and stress-dynamic-loading scenarios. A sixth dynamic experiment was performed with AWE to investigate

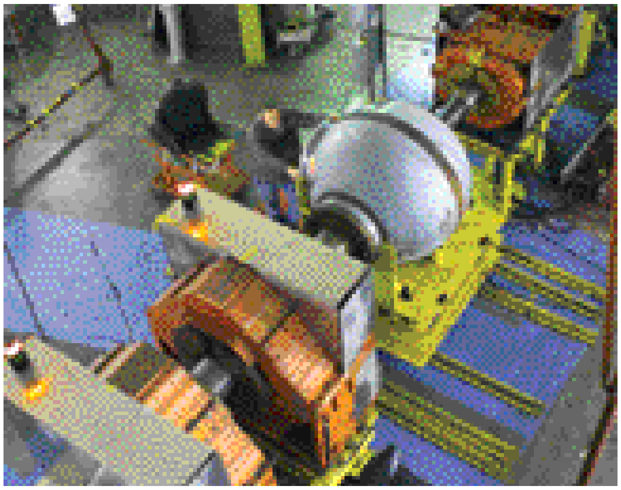

Fig. 2. Peter Pazuchanics (LANL) inspects a 3-ton steel vessel used to confine the explosions involved in many pRad experiments.[1]

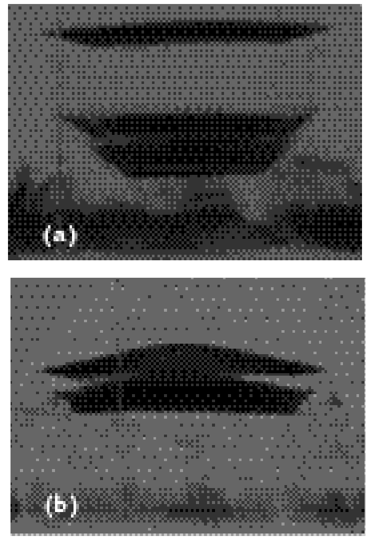

Fig. 4. Late-time (80 µs after the shock entered the steel) proton radiograph from the two 316L stainless-steel failure experiments fired in November 2002. (a) 1/2-in.-thick sample. (b) 1/4-in.-thick sample.

the bonding strength of a thin lead layer bonded to an aluminum disk. Of the 42 dynamic experiments, 18 were devoted to the study of HE burn characteristics. Three of these experiments were designed to study the equation of state of HE burn products, two measured the width of the HE detonation zone in PBX-9501 and PBX-9502 high explosives, and the remaining experiments were designed to study the characteristics of detonating HE (Fig. 3). An experimental series named AFX-221 was performed for the U.S. Air Force to study the HE burn characteristics around objects embedded within the HE. Nine dynamic experiments were performed to study the spall-formation process in aluminum, copper, tin, and 316L stainless steel (Fig. 4). Two experiments were performed to study the fracture mechanisms of thin cylinders of titanium. The third experiment was a classified configuration containing the largest HE load (~10 lb) ever fired at LANSCE. This experiment is being carefully simulated to provide model data for comparison to the data collected at pRad.

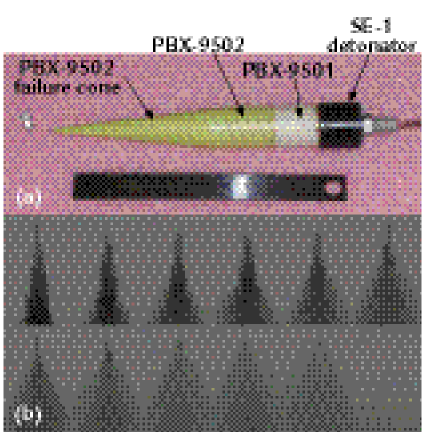

Fig. 3. (a) Failure cone designed to study the detonation characteristics of PBX-9502. (b) Proton radiographs at various times throughout the detonation of the failure cone showing characteristics of the detonation front as it propogates to the end of the failure cone.

In addition to the experiments performed in 2002, two new radiography systems were commissioned. The first was installed in the spring to study the possibility of using Cerenkov light, rather than scintillation light, to image the proton distribution. The accelerator was tuned to provide ~ 500-MeV protons, which is the threshold energy for protons to emit Cerenkov light in water, to the standard pRad magnetic imaging system. A new radiator and imaging system was built and installed to collect the Cerenkov light. This system successfully imaged very thin systems with a factor of ~ 40 improvement in contrast over the standard radiography system. The second new capability, a pRad microscope, was commissioned in the fall of 2002. This microscope system was designed to improve the radiographic resolution to study the mesoscale properties of dynamic systems. The commissioning effort was very successful in improving the resolution from the 200 µm achieved with the standard radiography system to 18 µm.

References

1. B. Fishbine, Los Alamos National Laboratory report LALP-03-003, p. 14.

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